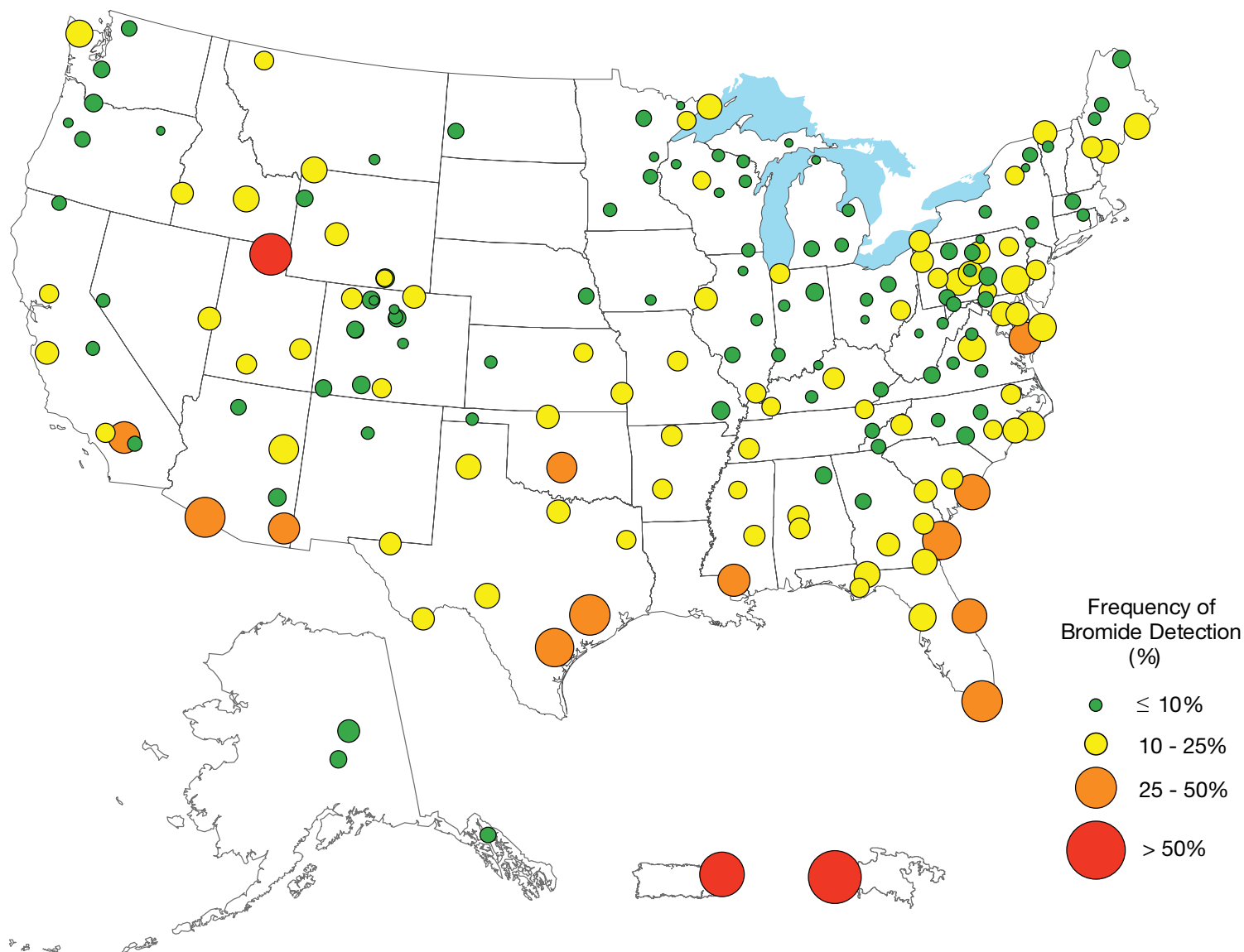
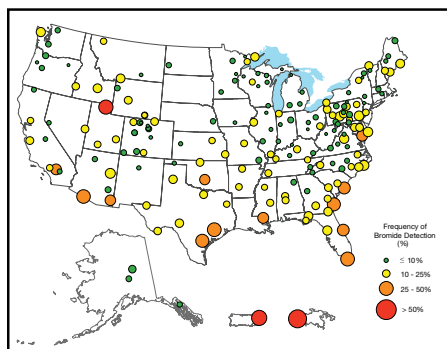




National Atmospheric Deposition Program

2012 Annual Summary





On the cover: The proportional circle map represents the detection frequency of bromide ion ($\text{Br}^- < 0.005 \text{ mg/L}$) in 2012 as a percentage of the valid NTN samples with precipitation. Bromide ion in precipitation is a new analyte within the NTN and AIRMoN. Refer to the maps on page 19 for the annual precipitation-weighted mean concentration and annual deposition of bromide ion.

When referencing maps or information in this report, please use the citation: National Atmospheric Deposition Program, 2013. National Atmospheric Deposition Program 2012 Annual Summary. NADP Data Report 2013-01. Illinois State Water Survey, University of Illinois at Urbana-Champaign, IL.

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2012 Highlights

The National Atmospheric Deposition Program (NADP) provides fundamental measurements that support informed decisions on environmental issues related to precipitation and atmospheric deposition chemistry, as well as atmospheric mercury and ammonia. NADP data are relevant to scientists, educators, policymakers, and the public. All data are available free of charge via the NADP website (<http://nadp.isws.illinois.edu>). Products available on this site include seasonal and annual averages, time series trend plots, and maps of concentration and deposition.

The NADP is composed of five networks, including the National Trends Network (NTN), the Atmospheric Integrated Research Monitoring Network (AIRMoN), the Mercury Deposition Network (MDN), the Atmospheric Mercury Network (AMNet), and the Ammonia Monitoring Network (AMoN). The table below summarizes the number of measurements made by each network this year.

Summary of Network Measurements, 2012

Network	Measurements	Period	No. of sites
NTN	13,251	weekly	261
MDN	4,309	weekly	112
AIRMoN	1,128	daily	7
AMNet	38,000	hourly	18
AMoN	1,137	two week	61

The NADP website is the primary tool for disseminating data from the five NADP networks. In 2012, there were more than 26,000 registered users. Data were downloaded nearly 28,000 times by agencies, universities, and K-12 schools.

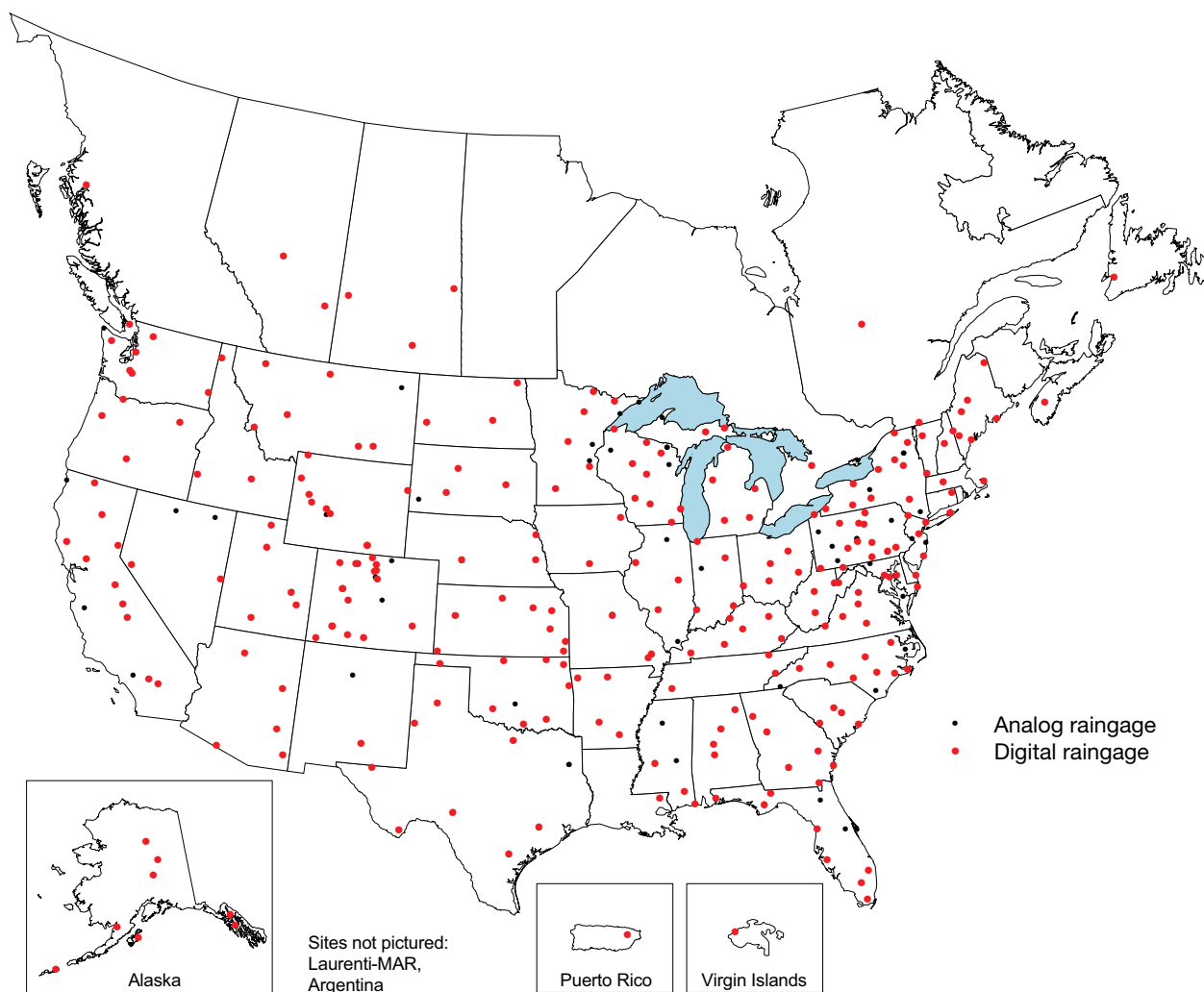
Highlights:

- 2012 is the 35th year of NADP operation. The first samples were collected in July 1978, at seven NTN sites (MN16, NC25, NE15, NH02, PA29, VA13, and WY18), all of which are still operating.
- NADP is measuring and reporting the concentration of bromide ions in all NTN and AIRMoN samples as a routine analyte.
- A new litterfall mercury monitoring initiative has begun to measure mercury and methyl mercury concentrations in forest litterfall (leaves, twigs, etc.). These dry deposition estimates will complement the MDN wet deposition monitoring and planned AMNet dry deposition estimates. Initiation of this trial network began in September 2012 with 14 sites, primarily in the Northeast and eastern U.S. Analysis and field support was provided through the U.S. Geological Survey.
- The Total Deposition Scientific Committee (TDep) operated for a full year as an NADP Scientific committee. Its goal is to improve estimates of atmospheric deposition by advancing the science of measuring and modeling of atmospheric wet, dry, and total deposition.
- Two state acid deposition networks were fully integrated in 2012: the New York Atmospheric Deposition Monitoring Network and the Pennsylvania Atmospheric Deposition Monitoring Network. This increased the number of NTN sites by six and ten sites, respectively.
- Two sites were added outside of North America during the year. A new AMNet site was established in Taiwan (TW01, Asia), and a new NTN

site was established in central Argentina (AG01, South America).

- NADP data and maps were used in 166 scientific publications.
- The Ammonia Monitoring Network (AMoN) has been in existence for five years, beginning as an initiative in October 2007, and as a full NADP network in 2010.

- Installation of electronic precipitation raingages at NADP wet-deposition sites continued (this page). At the end of 2012, 260 sites out of 312 total sites were operating with a digital precipitation gage. This represents 83% of the wet-deposition network sites.



The distribution of operating digital precipitation gages at NADP wet deposition sites, as of December 31, 2012.

NADP Background

The NADP was established in 1977 under State Agricultural Experiment Station (SAES) leadership to address the problem of atmospheric deposition and its effects on agricultural crops, forests, rangelands, surface waters, and other natural and cultural resources. In 1978, sites in the NADP precipitation chemistry network first began collecting weekly, wet-only deposition samples. Chemical analysis was performed at the Illinois State Water Survey's Central Analytical Laboratory (CAL), located at the University of Illinois, Urbana-Champaign. The network was established to provide data on amounts, temporal trends, and geographic distributions of the atmospheric deposition of acids, nutrients, and base cations by precipitation.

Initially, the NADP was organized as SAES North Central Regional Project NC-141, which all four SAES regions further endorsed in 1982 as Interregional Project IR-7. A decade later, IR-7 was reclassified as National Research Support Project No. 3 (NRSP-3), which it remains. NRSP projects are multistate activities that support research on topics of concern to more than one state or region of the country. Multistate projects involve the SAES in partnership with the USDA - Cooperative State Research, Education, and Extension Service (now National Institute of Food and Agriculture) and other universities, institutions, and agencies. In October 1981, the federally supported National Acid Precipitation Assessment Program (NAPAP) was established to increase understanding of the causes and effects of acidic precipitation. This program sought to establish a long-term precipitation chemistry network of sampling sites away from point source influences. Due to its experience in organizing and operating a national-scale network, the NADP agreed to coordinate operation of NAPAP's National Trends Network (NTN). To benefit from identical siting criteria and operating procedures and a shared analytical laboratory, NADP and NTN merged with the designation NADP/NTN. This merger brought

substantial new federal agency participation into the program. Many NADP/NTN sites were supported by the USGS, NAPAP's lead federal agency for deposition monitoring.

In October 1992, the AIRMoN joined the NADP. AIRMoN sites collect samples daily when precipitation occurs. AIRMoN samples are analyzed for the same analytes as NTN samples.

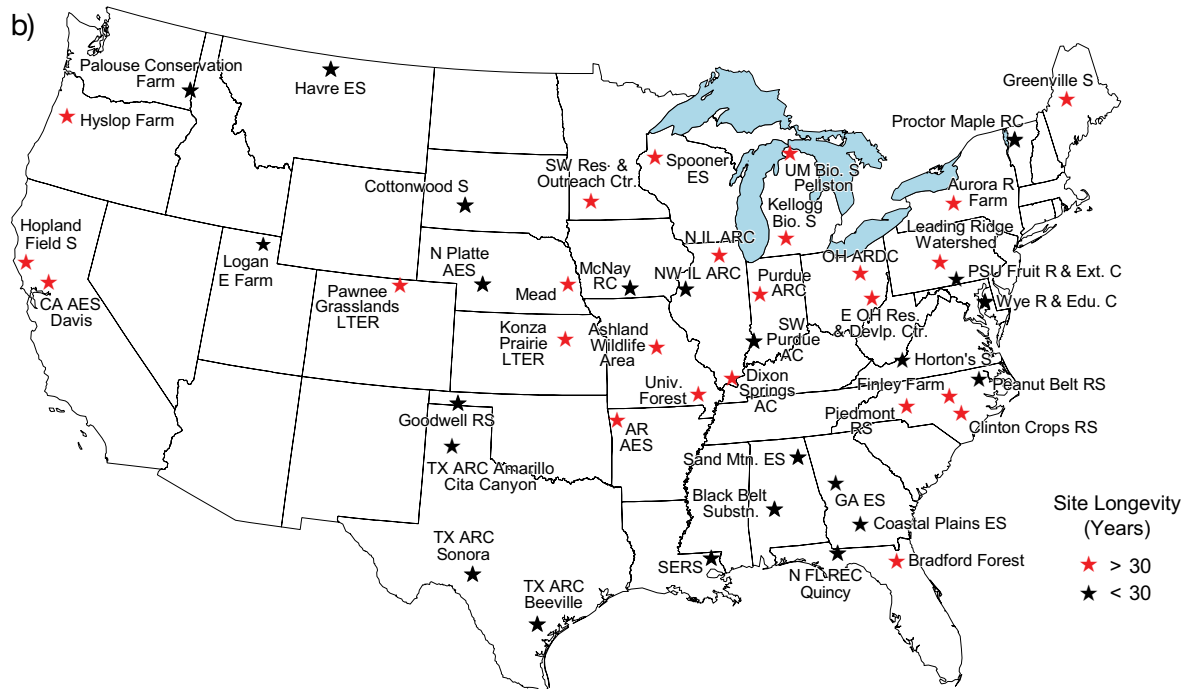
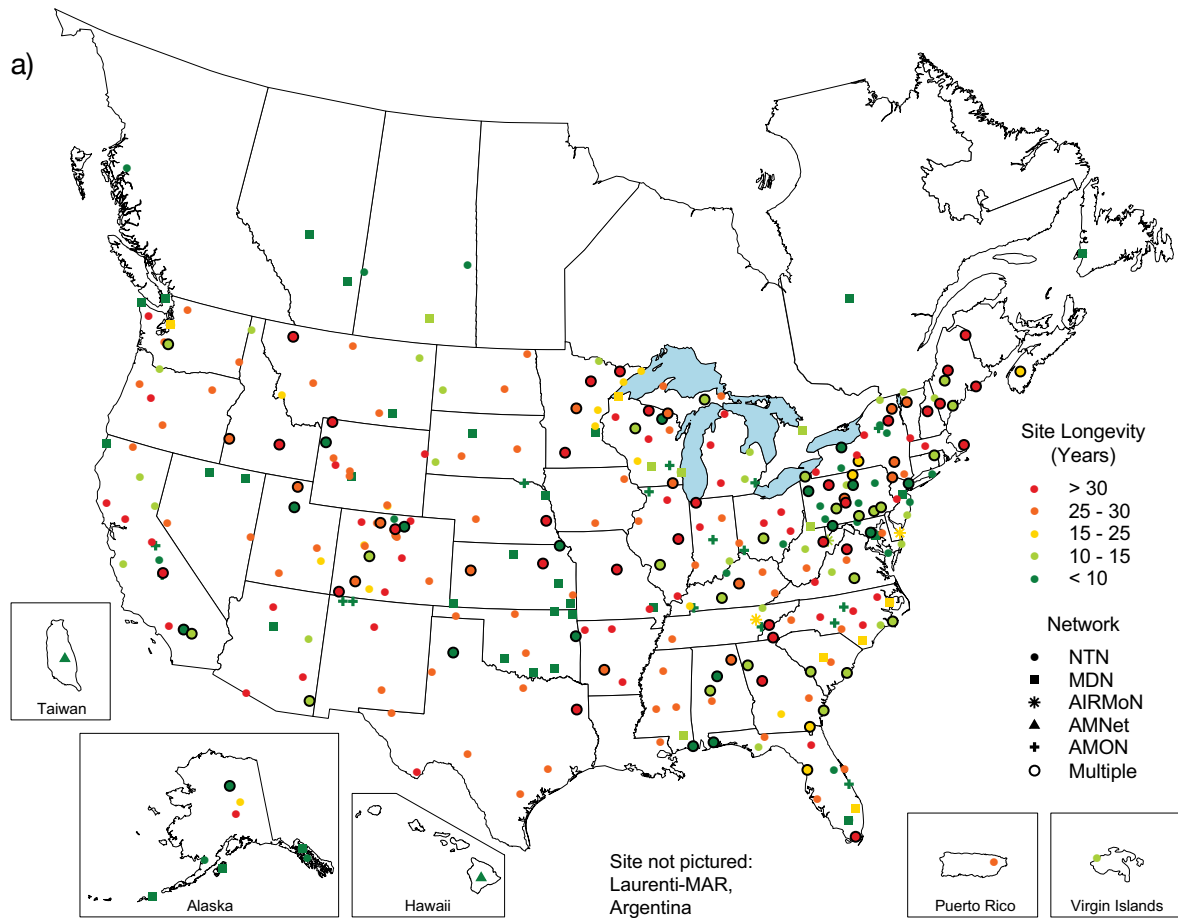
In January 1996, the NADP established the MDN, the third network in the organization. The MDN was formed to provide data on the wet deposition of mercury to surface waters, forested watersheds, and other receptors.

In October 2009, AMNet joined the NADP as its fourth network. AMNet measures the concentration of atmospheric mercury.

In October 2010, AMoN joined the NADP, measuring atmospheric ammonia concentrations using passive samplers.

The two maps on the next page show a) the location and the longevity of measurements at each of the NADP sites for all networks and b) the SAES network, representing many of the founding NTN sites and many with the longest sample records. Longevity of continuous measurement is a goal of the NADP.

SAES project NRSP-3 was renewed in 2009. It offers a unique opportunity for cooperation among scientists from land-grant and other universities, government agencies, and non-governmental organizations. It provides a framework for leveraging the resources of more than 250 agencies to address contemporary and emerging issues of national importance.



a) Site longevity of active NADP sites in each network, and b) the currently operating sites located at State Agricultural Experiment Stations (SAES).

About the Maps

This map series is a principal product of the NADP. It summarizes the results of network operation for the most recent complete calendar year in map form. Additional maps and related geographic information are available on the NADP website. Black dots mark site locations that meet NADP completeness criteria (see the NADP website for details). Open circles designate urban sites, defined as having at least 400 people per square kilometer (km^2) within a 15-km radius of the site.

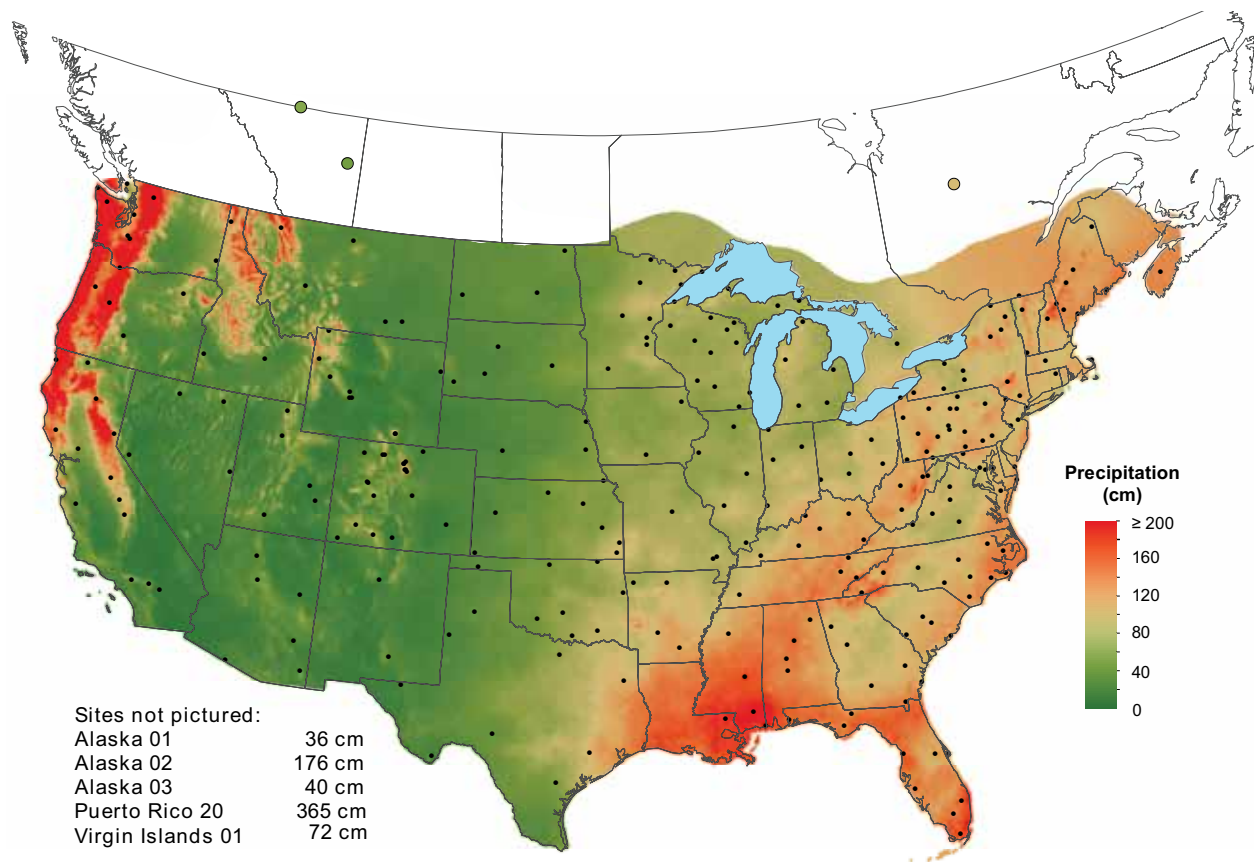
Colors are assigned by using site values to compute grid-point values across the nation. Sites within 500 km of each grid point are used in computations. Urban sites do not contribute to the contour surface. Colors represent interpolated values of concentration, deposition, or precipitation.

Precipitation values are an adapted version of the U.S. precipitation grid developed by the PRISM Climate Group ("Parameter-elevation Regressions on Independent Slopes Model," <http://prism.oregonstate.edu>, July 2013). These annual precipitation estimates

incorporate point data, a digital elevation model, and expert knowledge of complex climatic extremes to produce continuous grid estimates.

NADP precipitation observations are used to supplement the PRISM precipitation grids through an inverse distance weighing over 20 km around all NADP network sites (see the NADP website for specific information). PRISM precipitation data are strictly for the continental U.S., so the precipitation gradient north of the U.S./Canadian border is based solely on NADP precipitation data. The resulting precipitation map is used to generate the deposition maps.

The figure on the facing page has a continuous gradient of color from dark green (low values) to yellow (middle values) to dark red (high values). The dark green region begins at 0 centimeters (cm) ranging to over 200 cm (dark red). The remaining concentration and deposition maps follow this same format, with specified units on each map. All maps back to 1994 are available in this format from the NADP website.



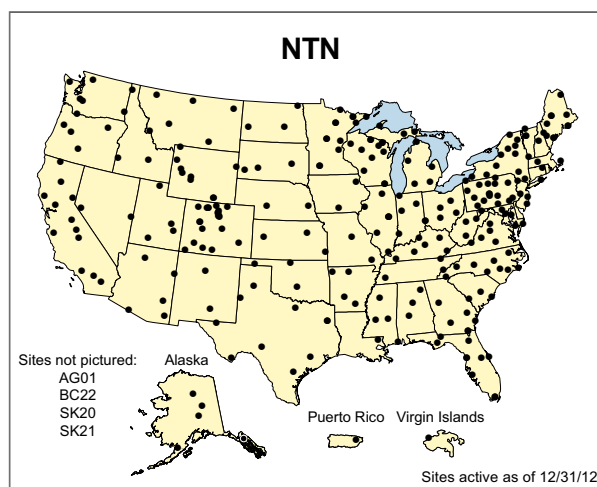
Total annual precipitation for 2012, using precipitation measurements from the NADP and PRISM (in cm).

National Trends Network (NTN)

The NTN is the largest North American network that provides a long-term record of precipitation chemistry. Sites are located away from urban areas and point sources of pollution. Each site has a precipitation collector and raingage. The automated collector ensures sampling only during precipitation (wet-only sampling). Site operators follow standard operating procedures to help ensure NTN data comparability and representativeness across the network. Weekly samples are collected each Tuesday morning, using containers provided by the CAL. All samples are sent to the CAL for analysis of free acidity (H^+ as pH), specific conductance, and calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), bromide (Br^-), and ammonium (NH_4^+) ions. The CAL also measures orthophosphate ions (PO_4^{3-} , the inorganic form), but only for quality assurance as an indicator of sample contamination. The CAL reviews field and laboratory data for accuracy and completeness, and flags samples that were mishandled, compromised by equipment failure, or grossly contaminated. Data from the NTN are freely available from the NADP website (<http://nadp.isws.illinois.edu/ntn/>).

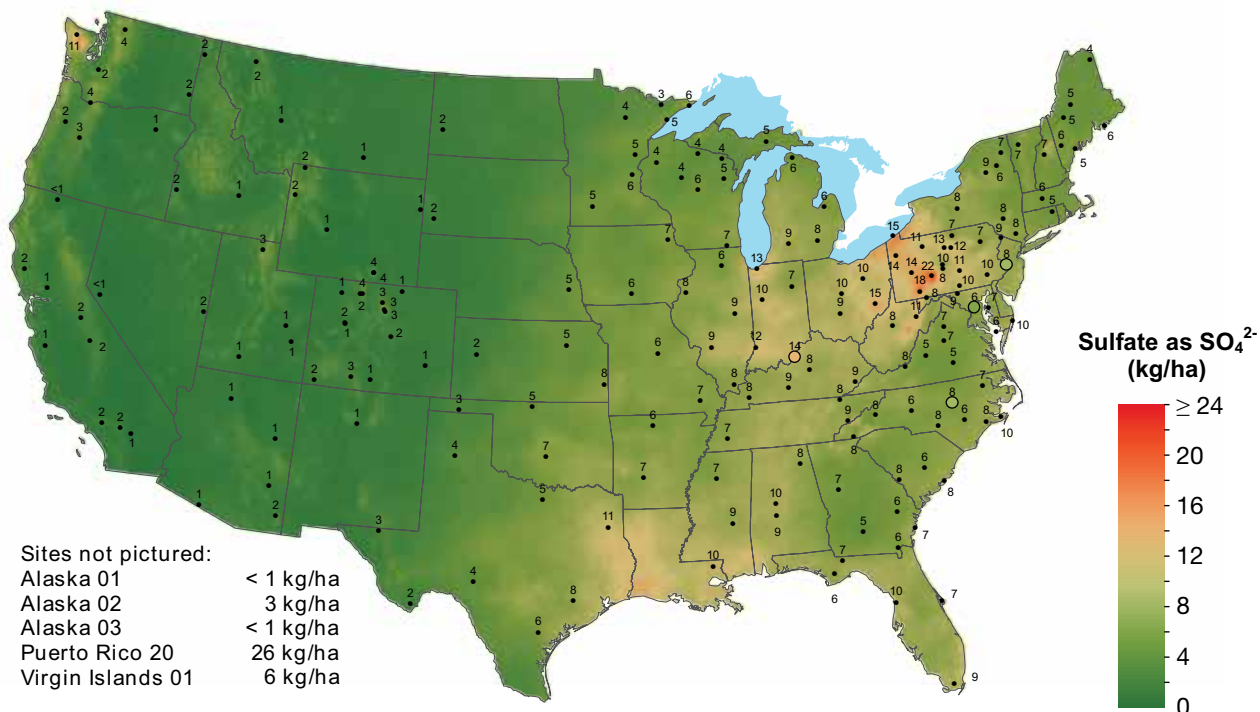
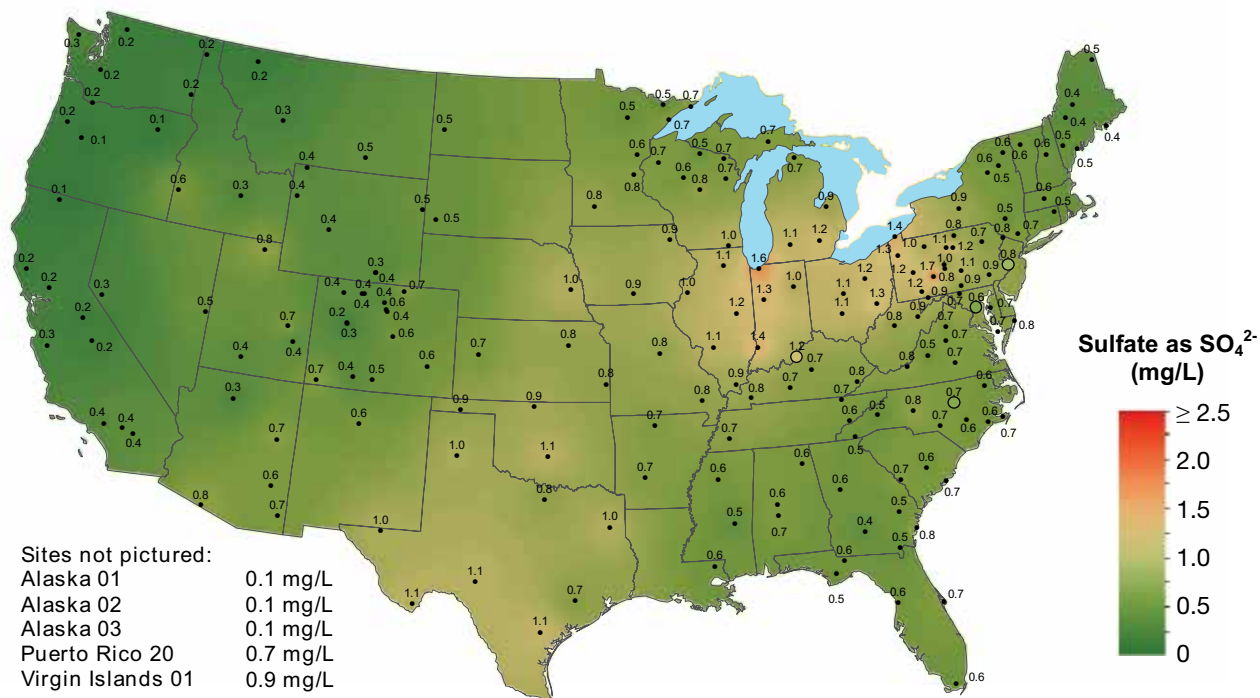
NTN Maps

The maps on pages 11 through 19 show precipitation-weighted mean concentration and annual wet deposition for select acidic ions, nutrients, and base

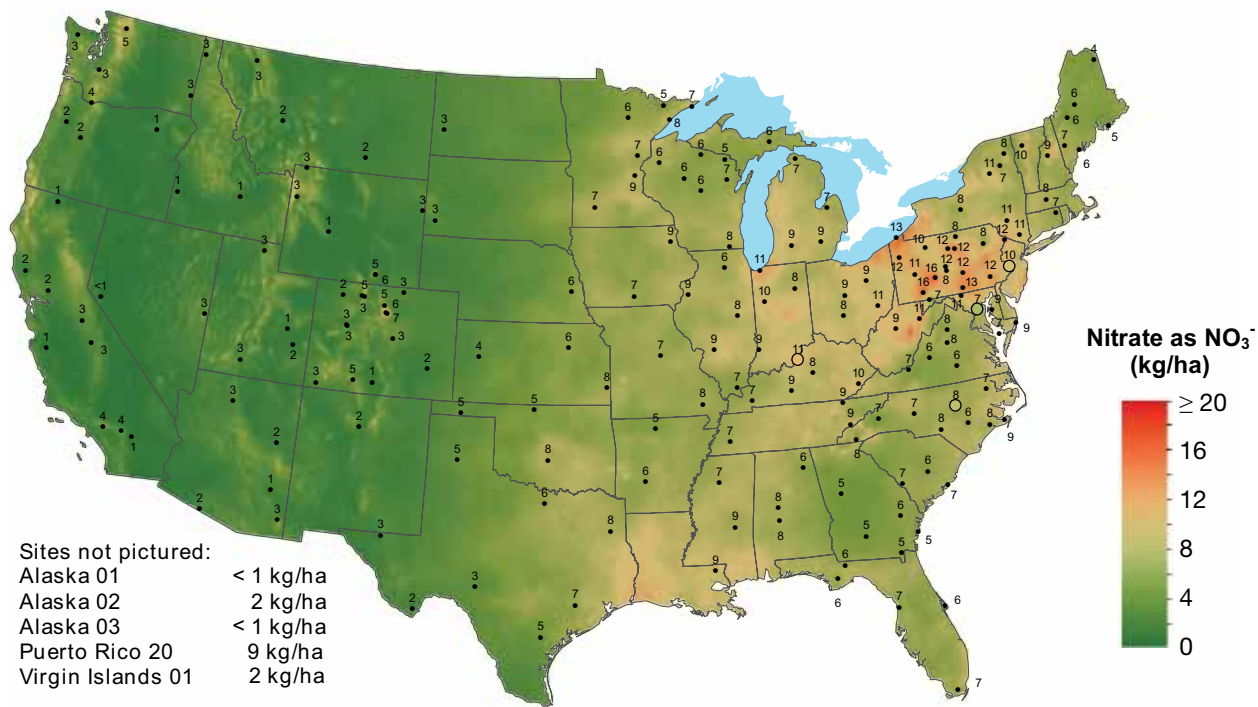
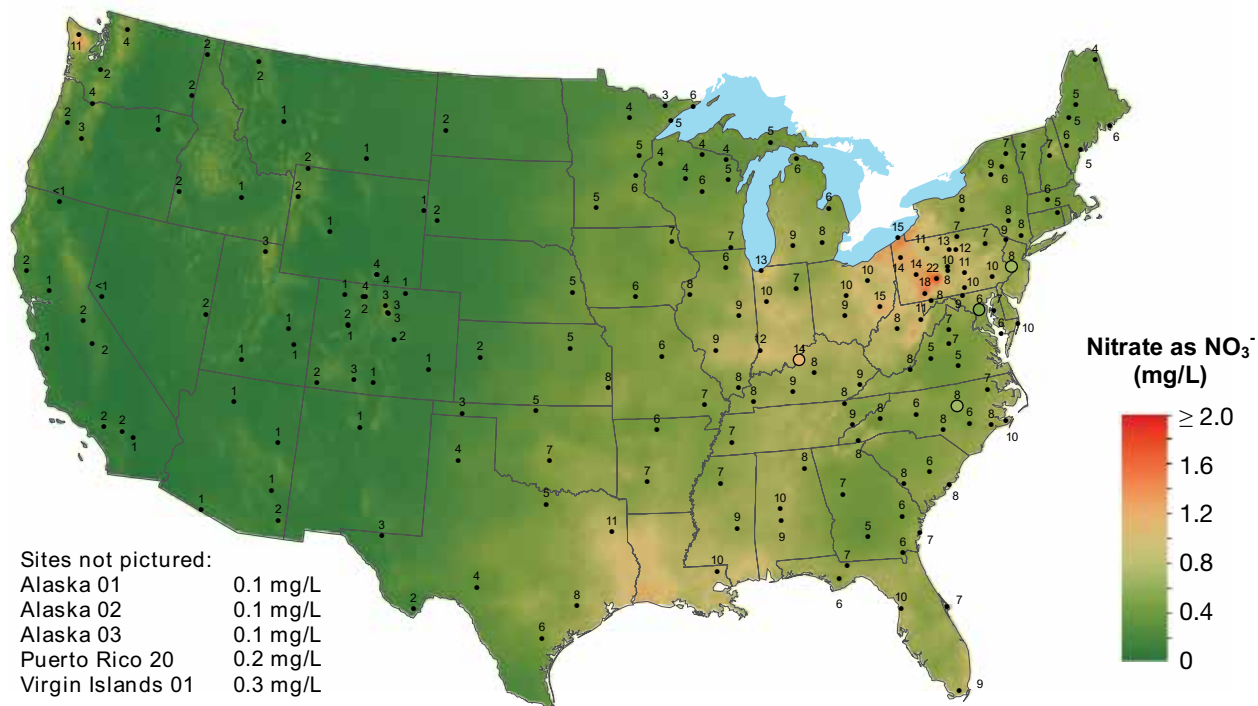


cations. Spatial variability in these species can be seen both on a regional and a national scale. In 2012, 198 of the 261 active sites met NADP completeness criteria. Concentration and deposition maps are included for SO_4^{2-} , NO_3^- , NH_4^+ , pH, Ca^{2+} , Mg^{2+} , Cl^- , and Br^- . Maps of Na^+ and K^+ are not included in this report, but are available from the NADP website.

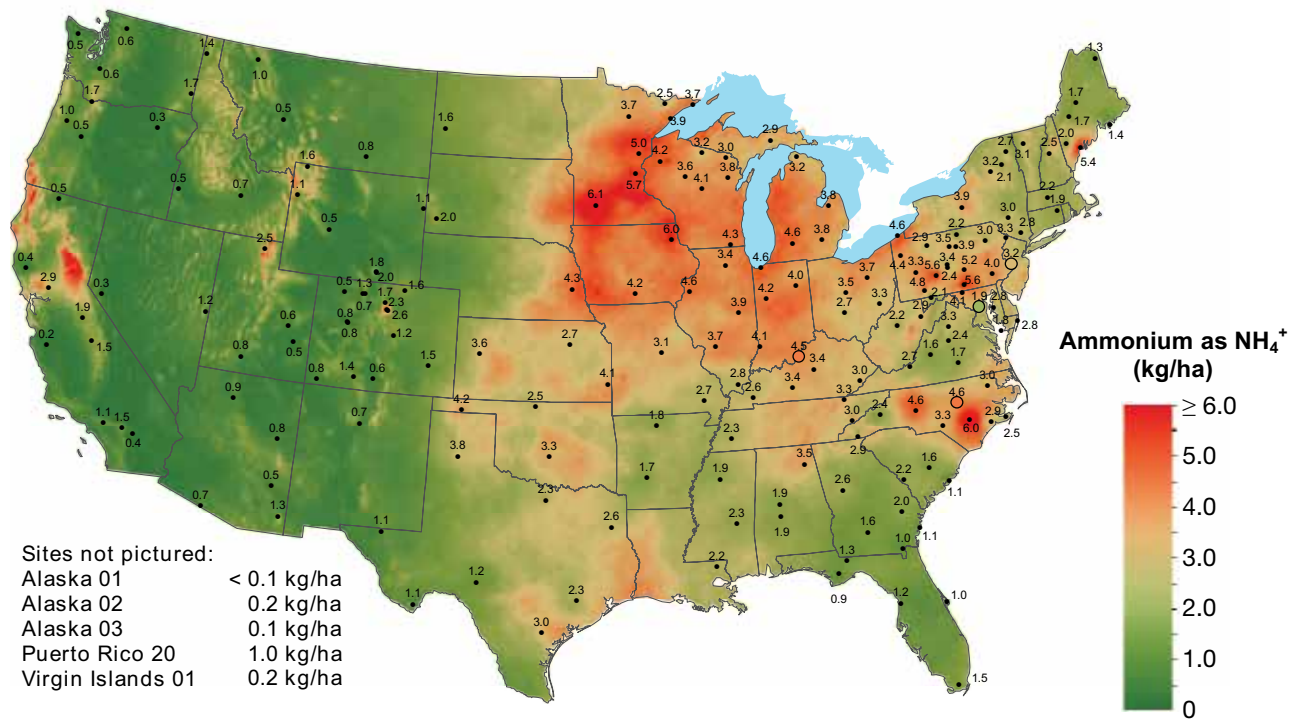
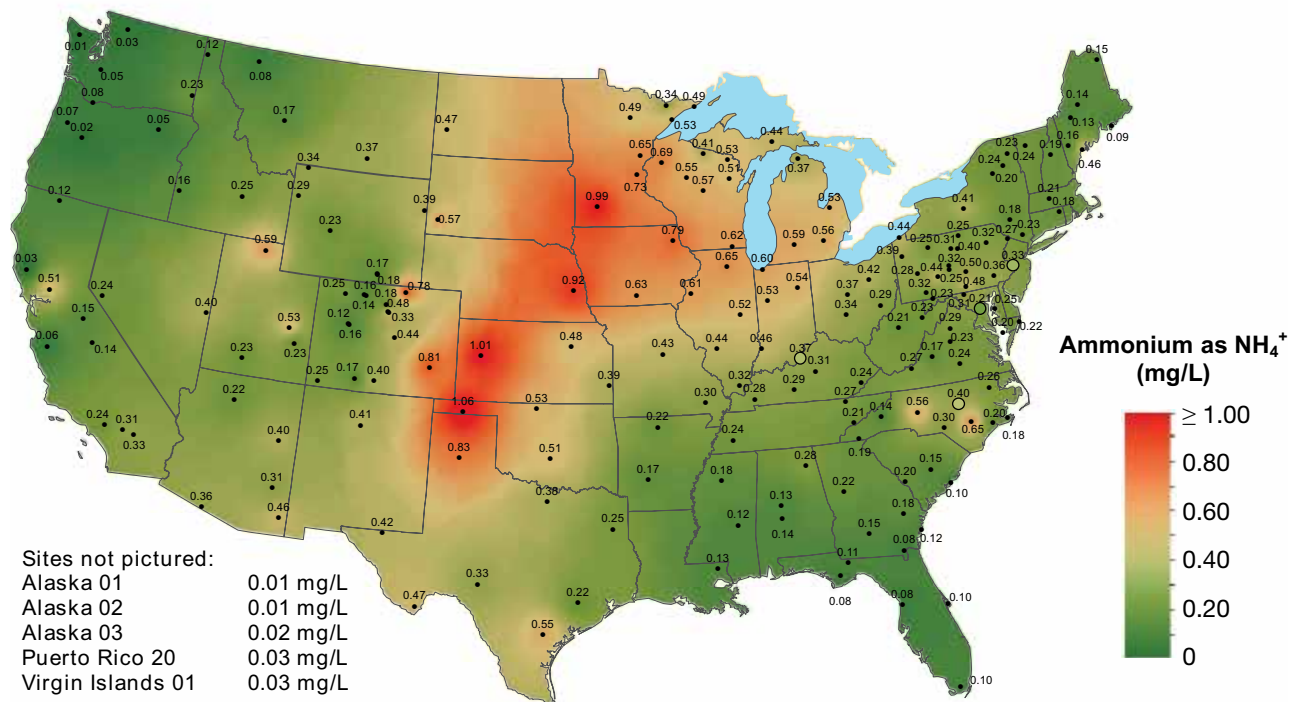
Maps for wet deposition of inorganic nitrogen ("N", i.e., $NO_3^- + NH_4^+$) and nitrogen + sulfur ("N + S") are also included. N + S (i.e., $NO_3^- + NH_4^+ + SO_4^{2-}$) is mapped as hydrogen ion equivalents per hectare for the year (eq/ha).



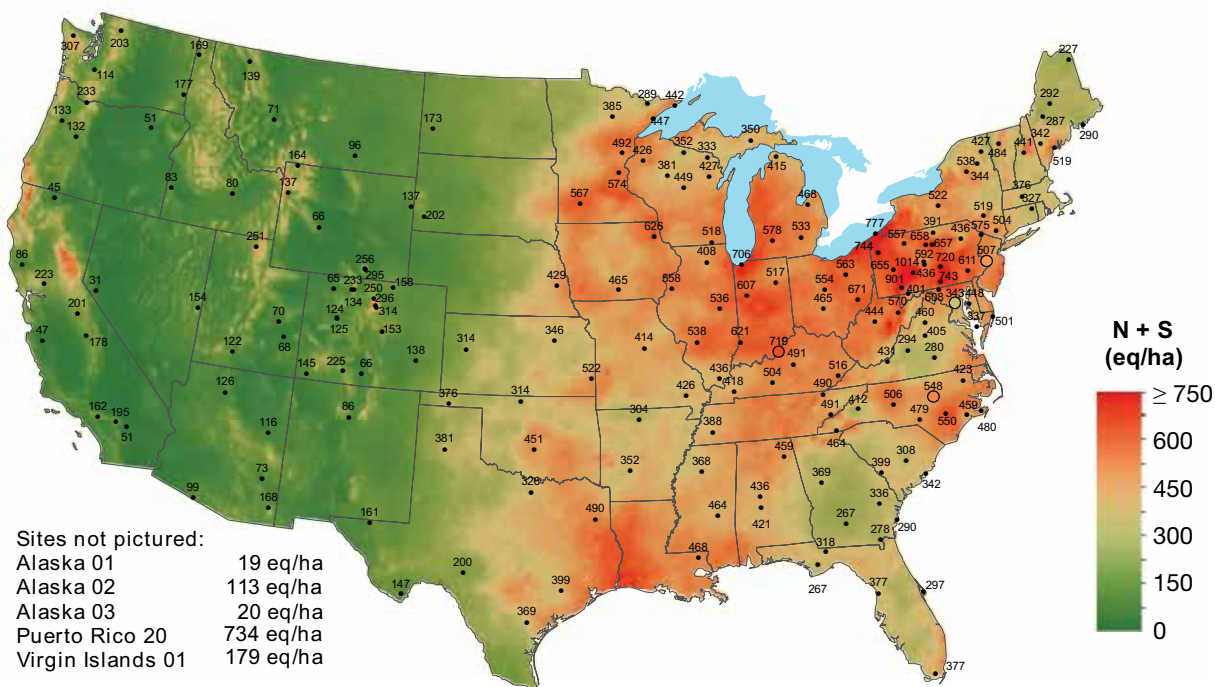
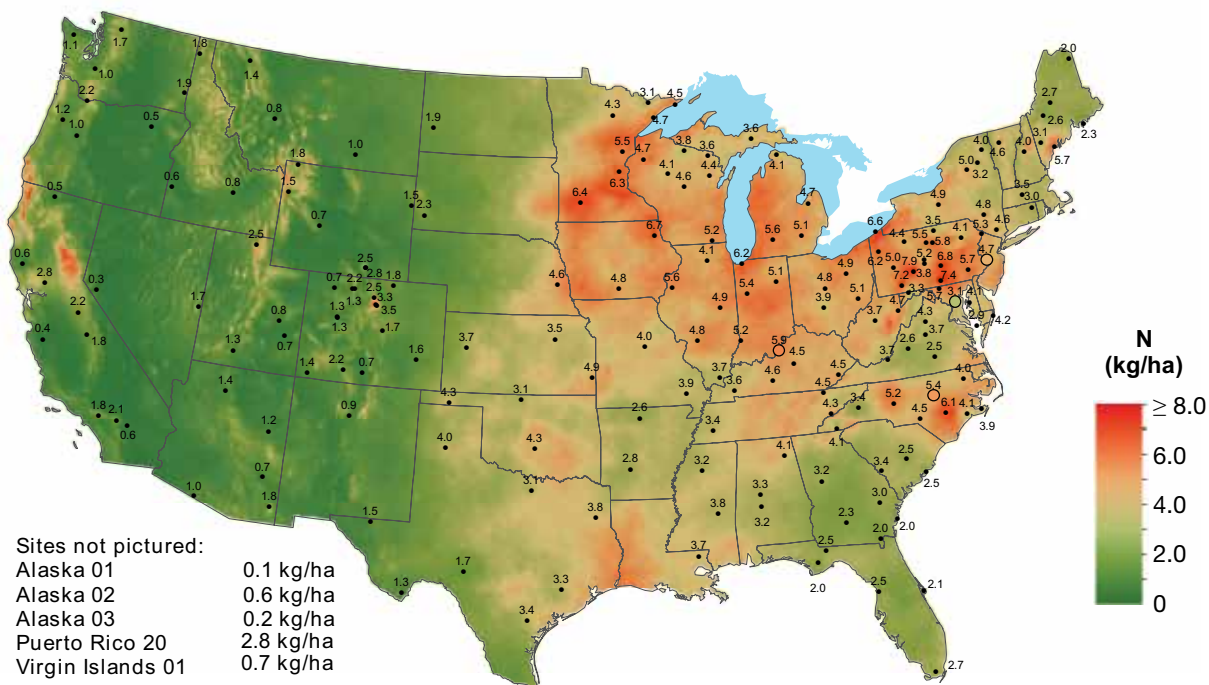
Sulfate ion concentration (top) and wet deposition (bottom), 2012.



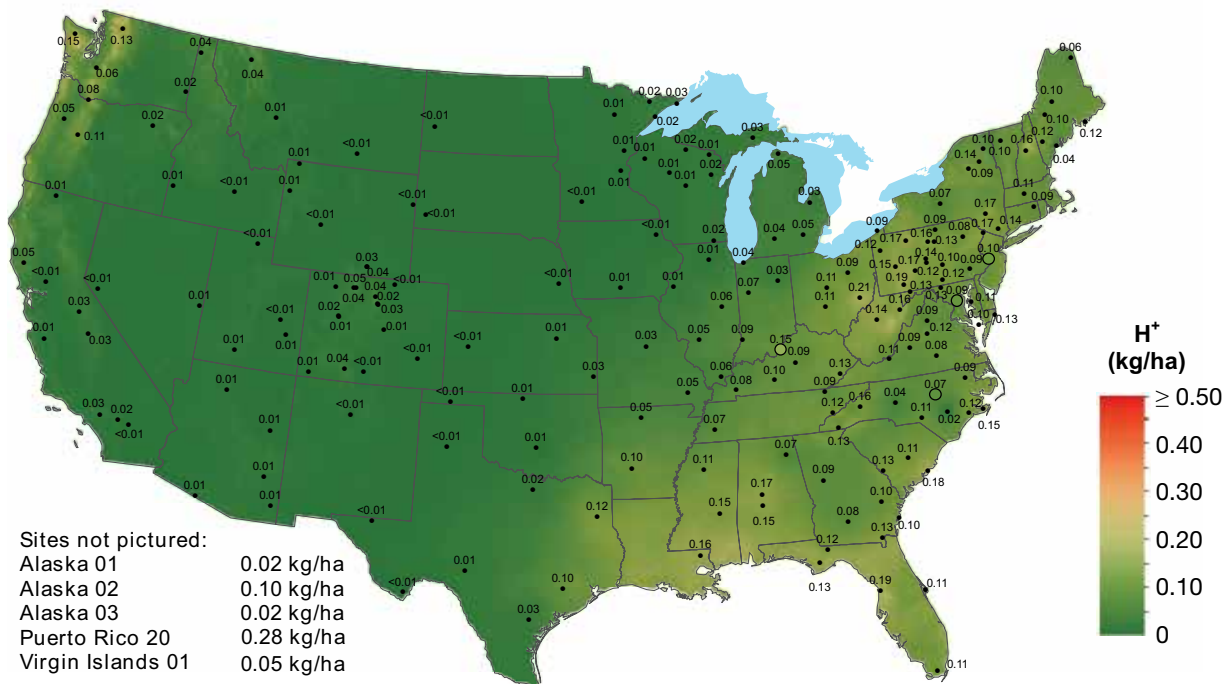
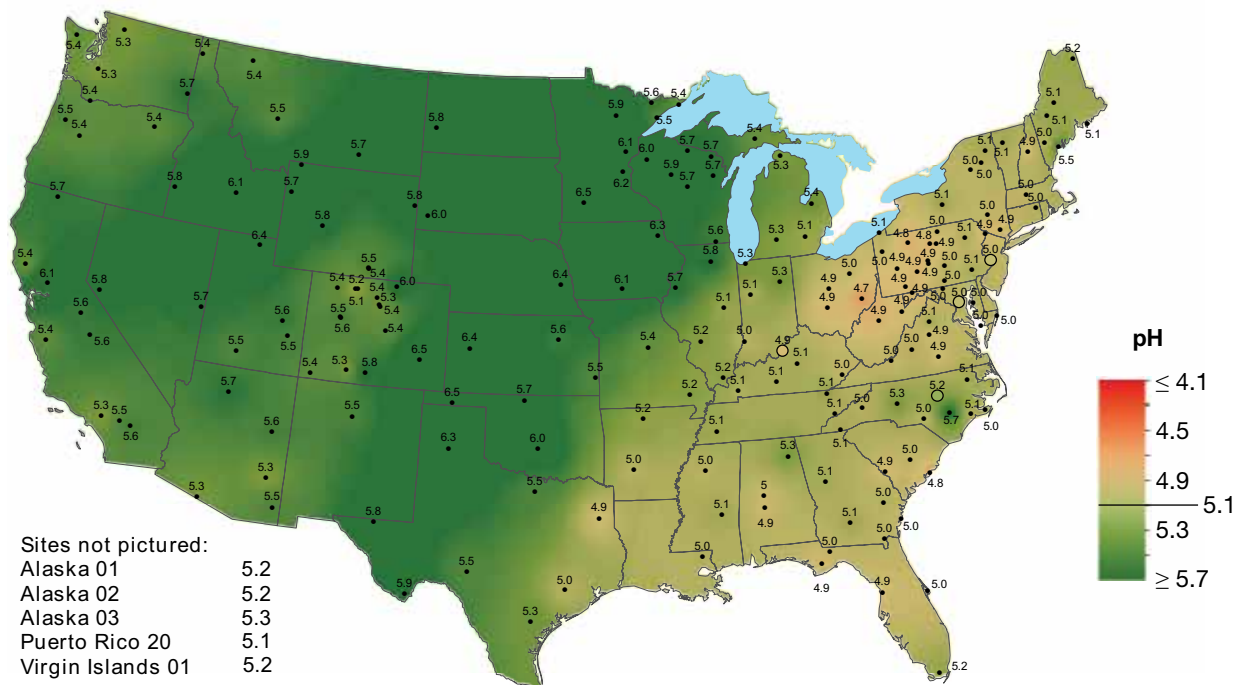
Nitrate ion concentration (top) and wet deposition (bottom), 2012.



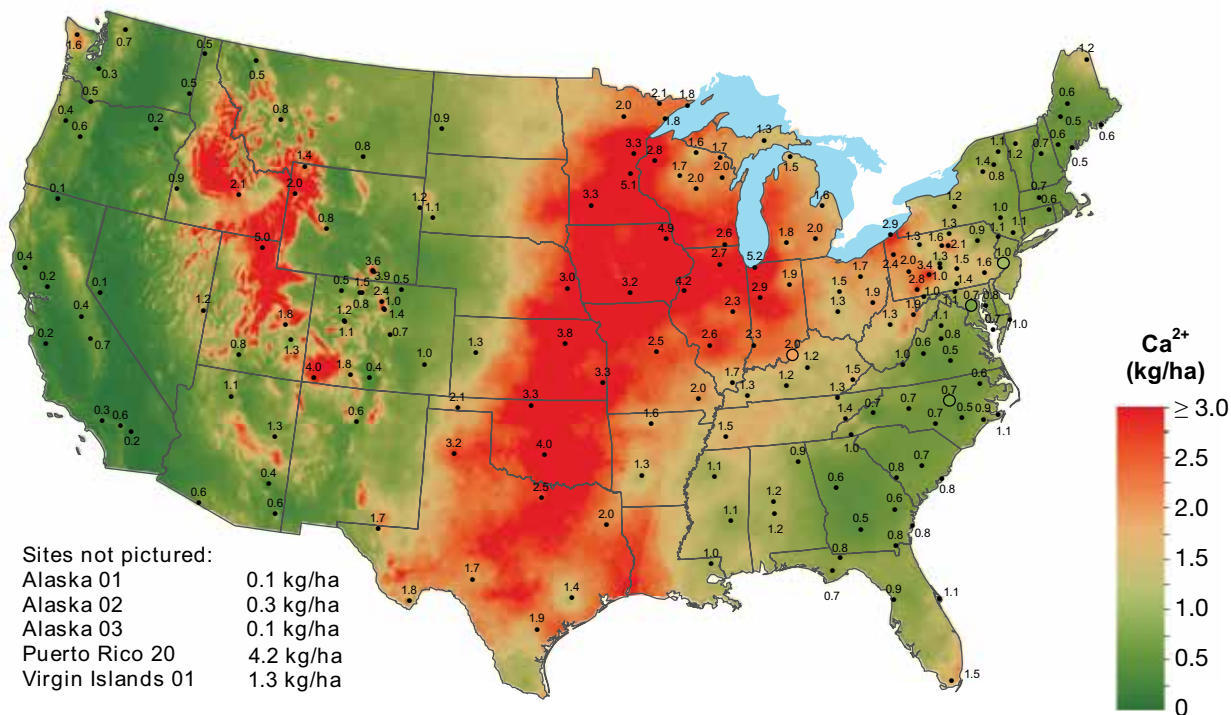
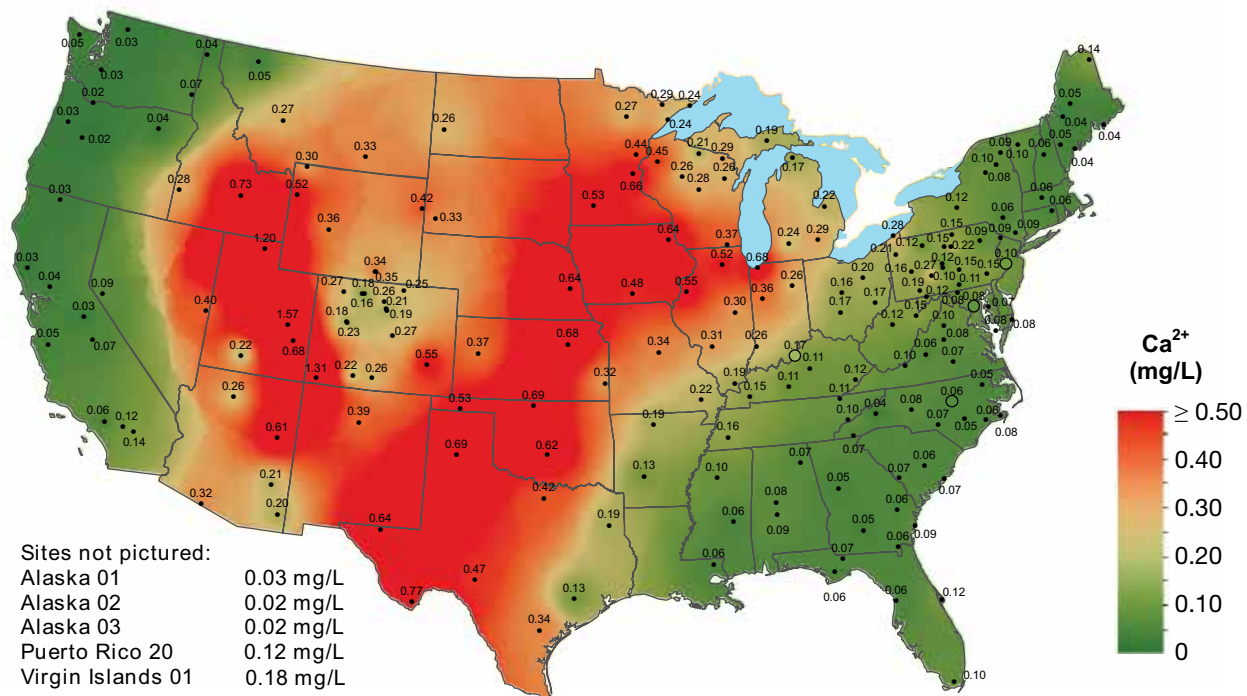
Ammonium ion concentration (top) and wet deposition (bottom), 2012.



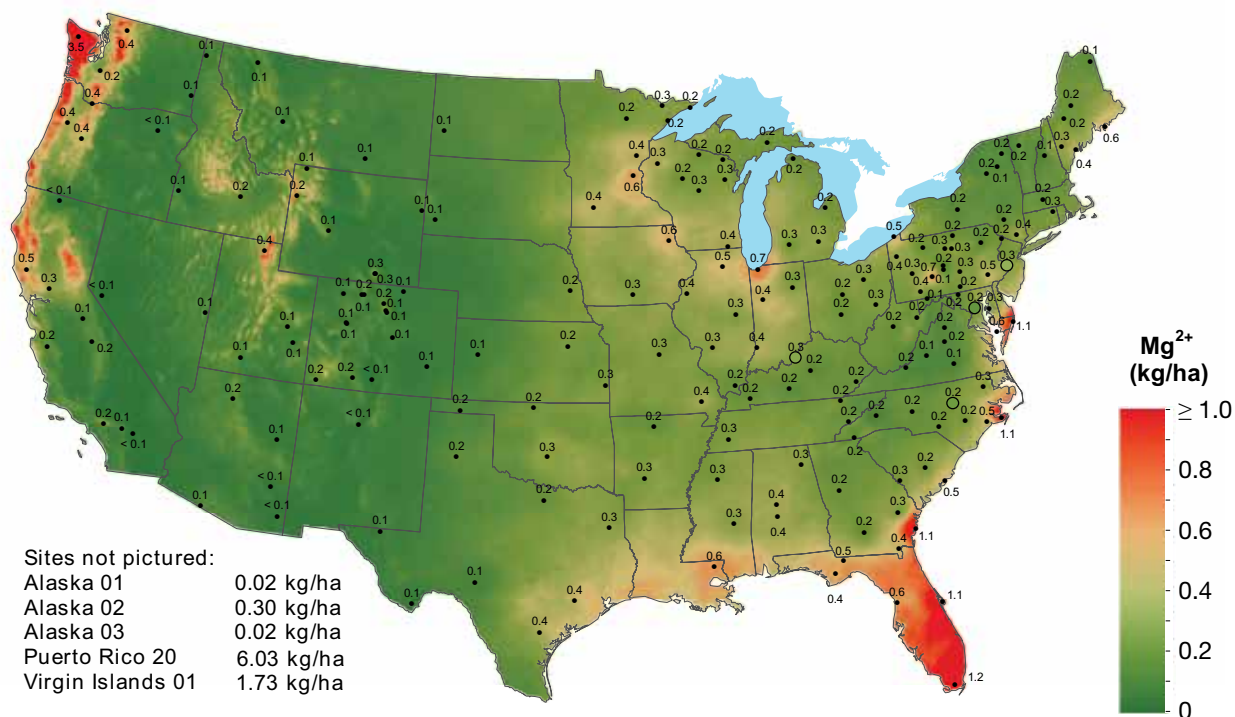
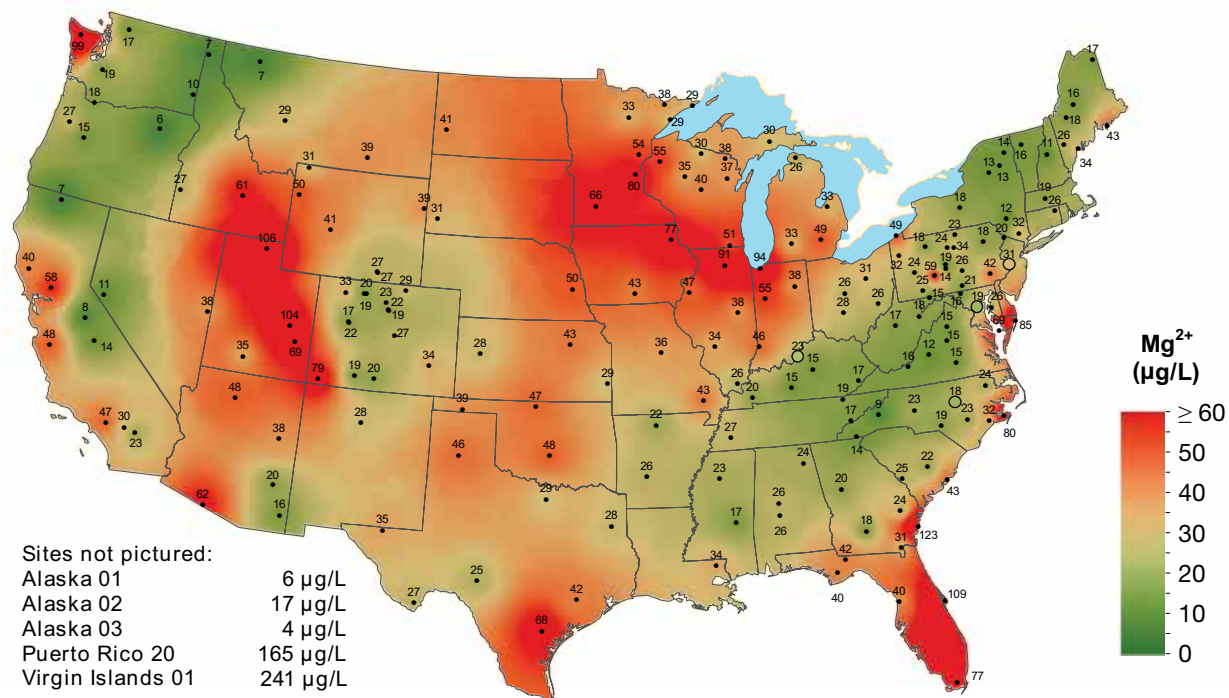
**Inorganic nitrogen wet deposition from nitrate and ammonium (top)
and nitrogen plus sulfur wet deposition from nitrate, ammonium, and sulfate (bottom), 2012.**



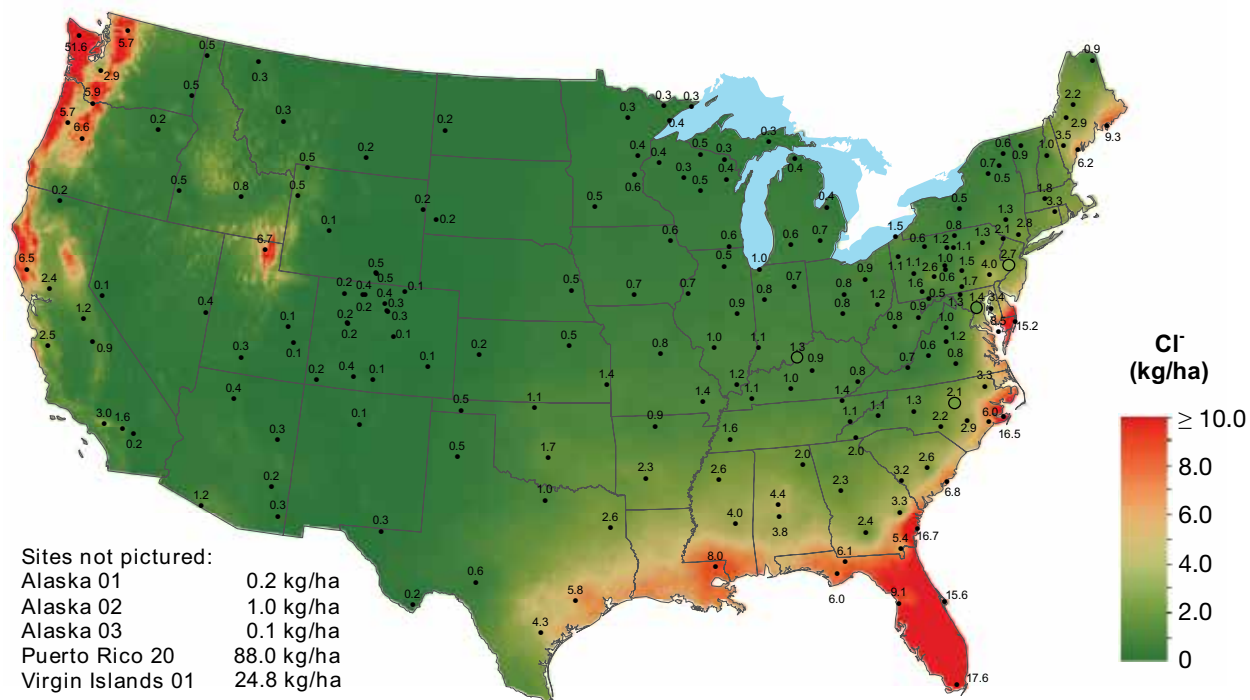
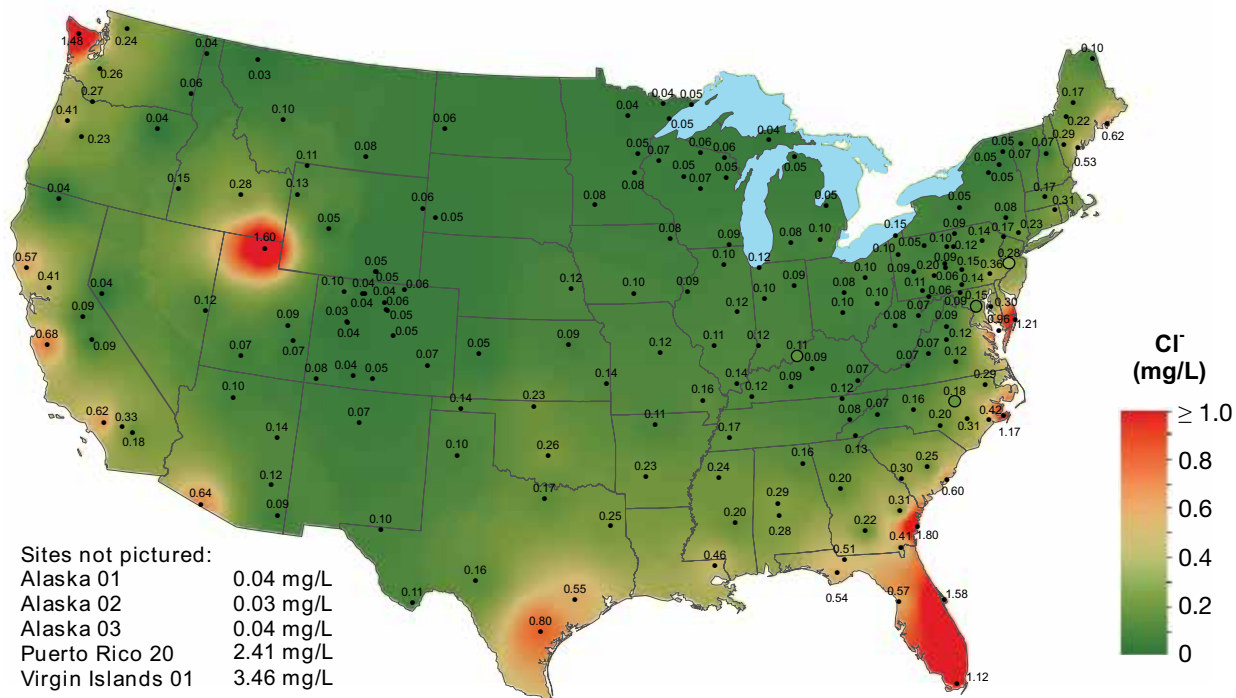
Hydrogen ion concentration as pH (top) and wet deposition (bottom), 2012.
 Typically, a precipitation pH of less than 5.1 is considered acidic.



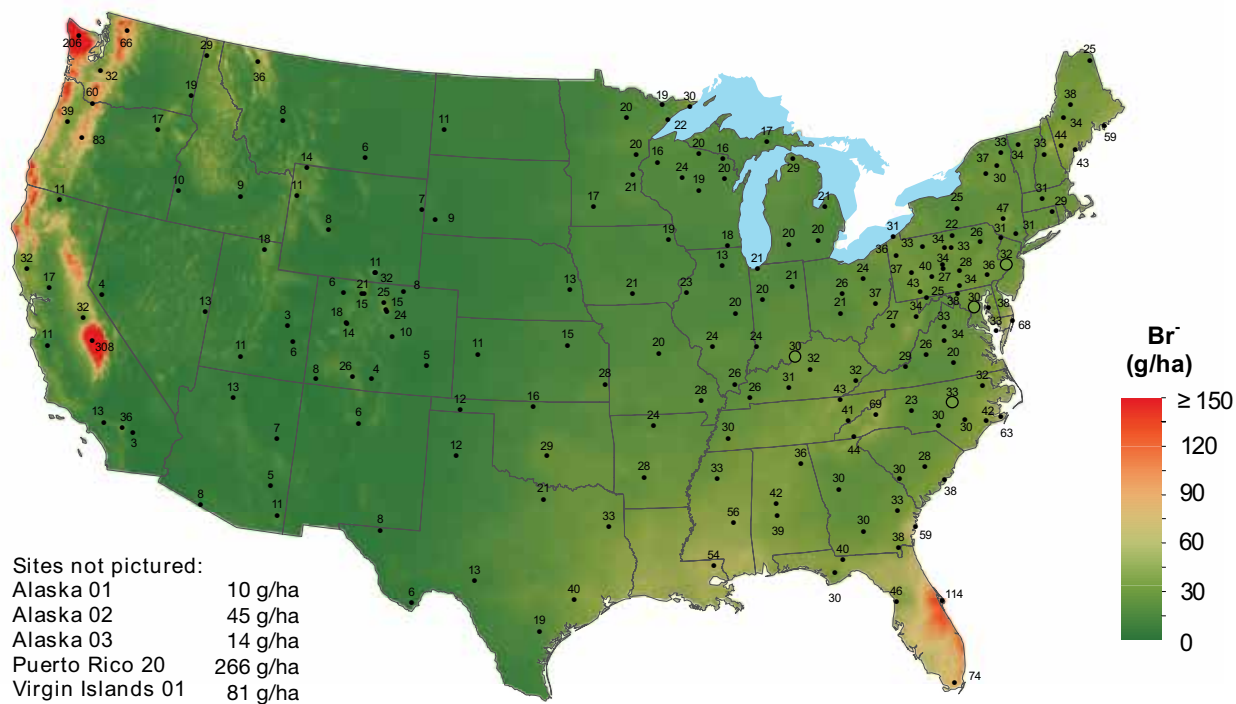
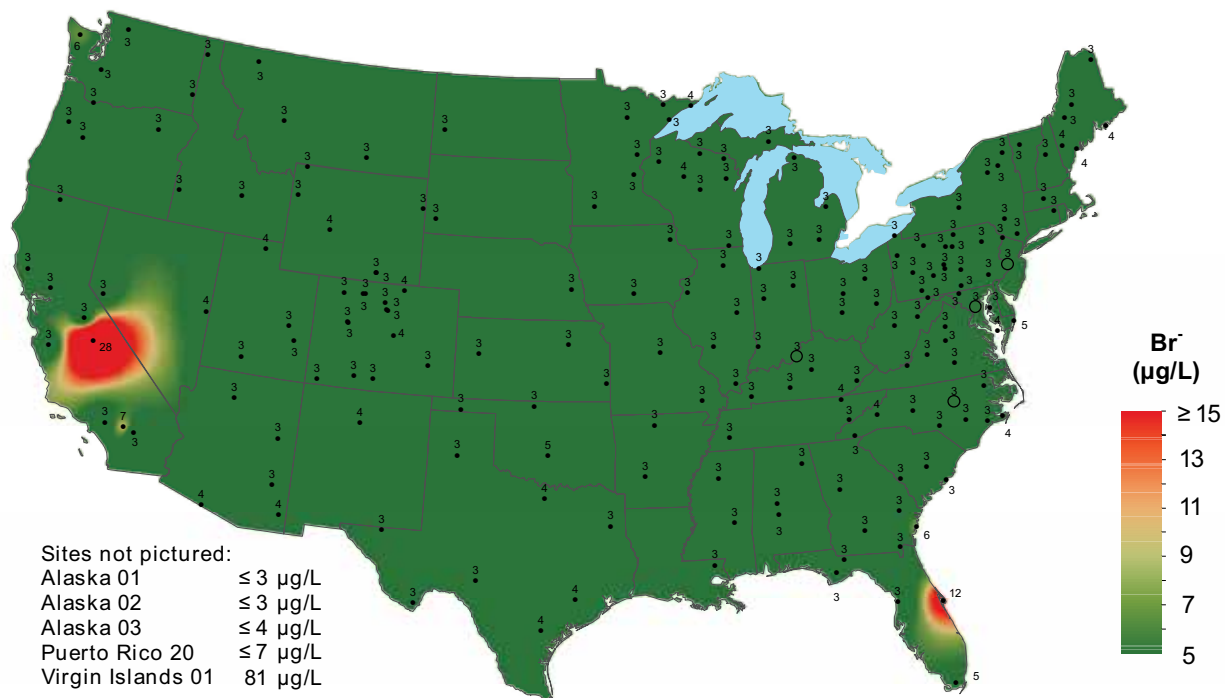
Calcium ion concentration (top) and wet deposition (bottom), 2012.



Magnesium ion concentration (top) and wet deposition (bottom), 2012.



Chloride ion concentration (top) and wet deposition (bottom), 2012.



Bromide ion concentration (top) and wet deposition (bottom), 2012. Note: the bromide reporting limit is 5 $\mu\text{g/L}$, and lower values are set, by NADP protocol, to one-half the reporting limit (~ 3 $\mu\text{g/L}$). Refer to the cover figure for the frequency of samples at each site above the reporting limit.

Atmospheric Integrated Research Monitoring Network (AIRMoN)

At AIRMoN sites samples are collected daily within 24 hours of the start of precipitation, often providing data for individual storm events. Single-storm data facilitate studies of atmospheric processes and the development and testing of computer simulations of these processes, such as the NOAA/ HYSPLIT fate and transport model. Back trajectories for all AIRMoN samples are provided at <http://nadp.isws.illinois.edu/AIRMoN>. Rapid release of data from this network is an AIRMoN goal.

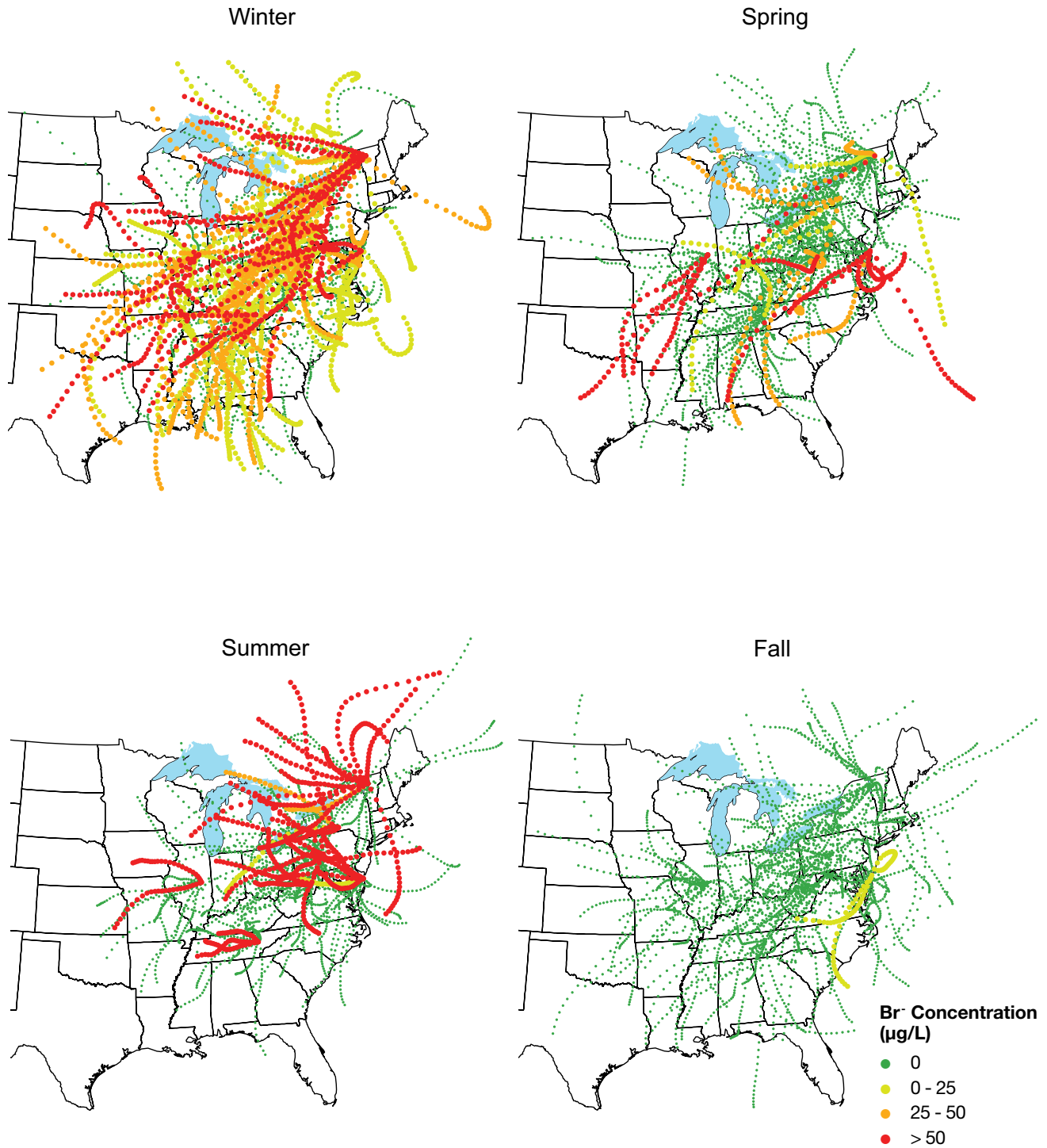
AIRMoN sites are equipped with the same wet-only deposition collector used at NTN sites. Each site also has a standard stick-type precipitation gage for reporting total precipitation (although digital gages are being incorporated). Samples are refrigerated after collection and are shipped in chilled, insulated containers to the CAL for analysis. Samples remain refrigerated until they are analyzed. Refrigeration retards potential chemical changes, such as with NH_4^+ and PO_4^{3-} . Chemical analyses and data screening procedures for AIRMoN and NTN are similar.

The twenty-four hour back trajectory plots (using NOAA's HYSPLIT model) on page 21 illustrate the back trajectory paths of air at 1500 meters starting altitude where wet deposition occurred. The back trajectories are color-coded to reflect the differing Br^- concentrations in the individual daily samples. These



back trajectory pathways are organized into seasonal figures; meteorological winter (i.e., December, January, and February) spring (March, April, May), summer (June, July, and August), and fall (September, October, and November), 2012.

Bromide ion is a new analyte in the AIRMoN, and these individual events can be referenced back to the NTN annual concentration and deposition maps on page 19, and on the 2012 Annual Summary cover.

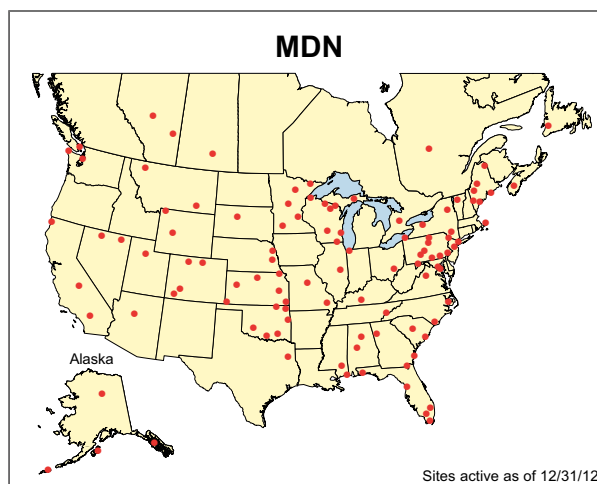


Twenty-four hour back trajectory plots of bromide concentration (in $\mu\text{g/L}$) for all event precipitation samples, as measured by AIRMoN. Back trajectories are shown by season (winter = December, January, and February; spring = March, April, May; etc.), 2012. All back trajectories were calculated using a starting altitude of 1500 meters.

Mercury Deposition Network (MDN)

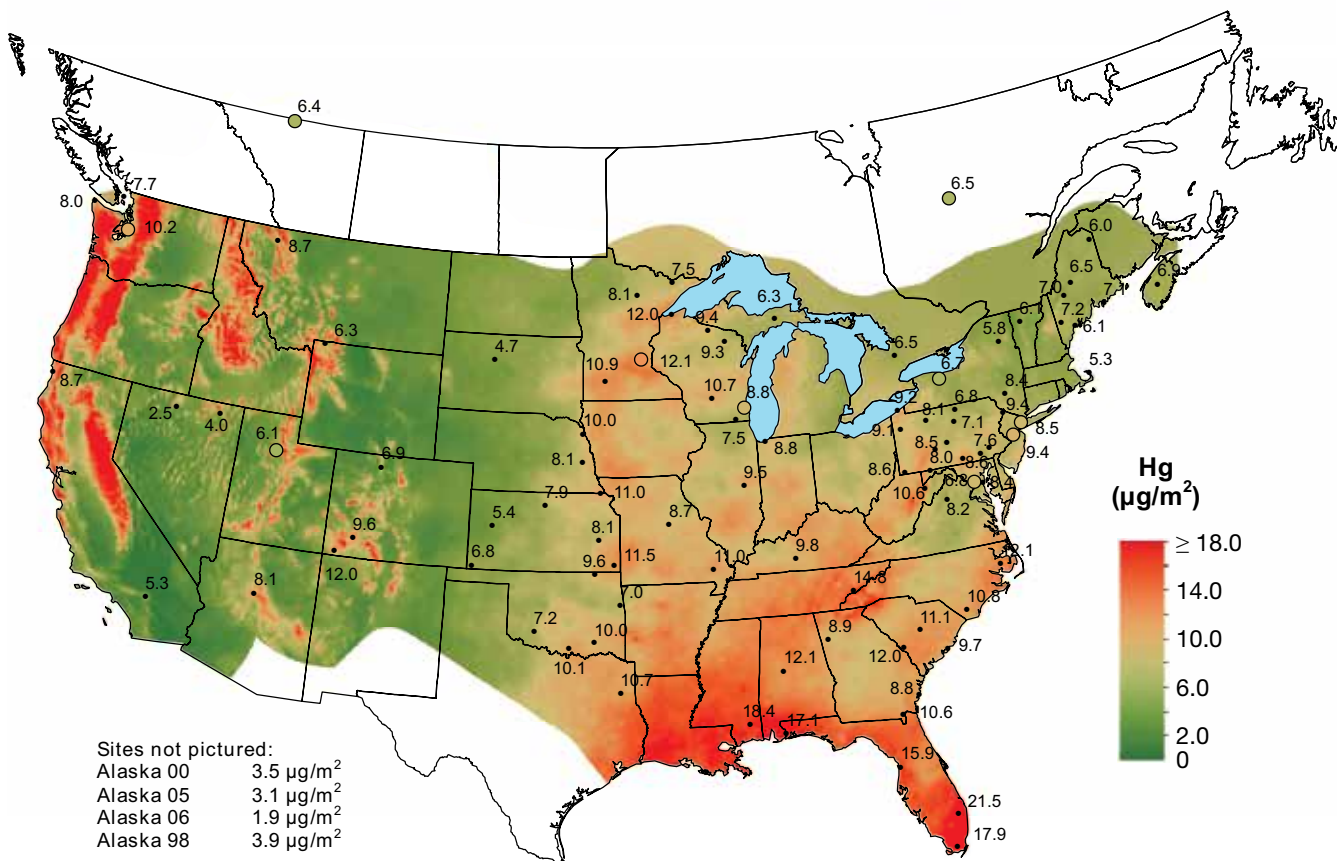
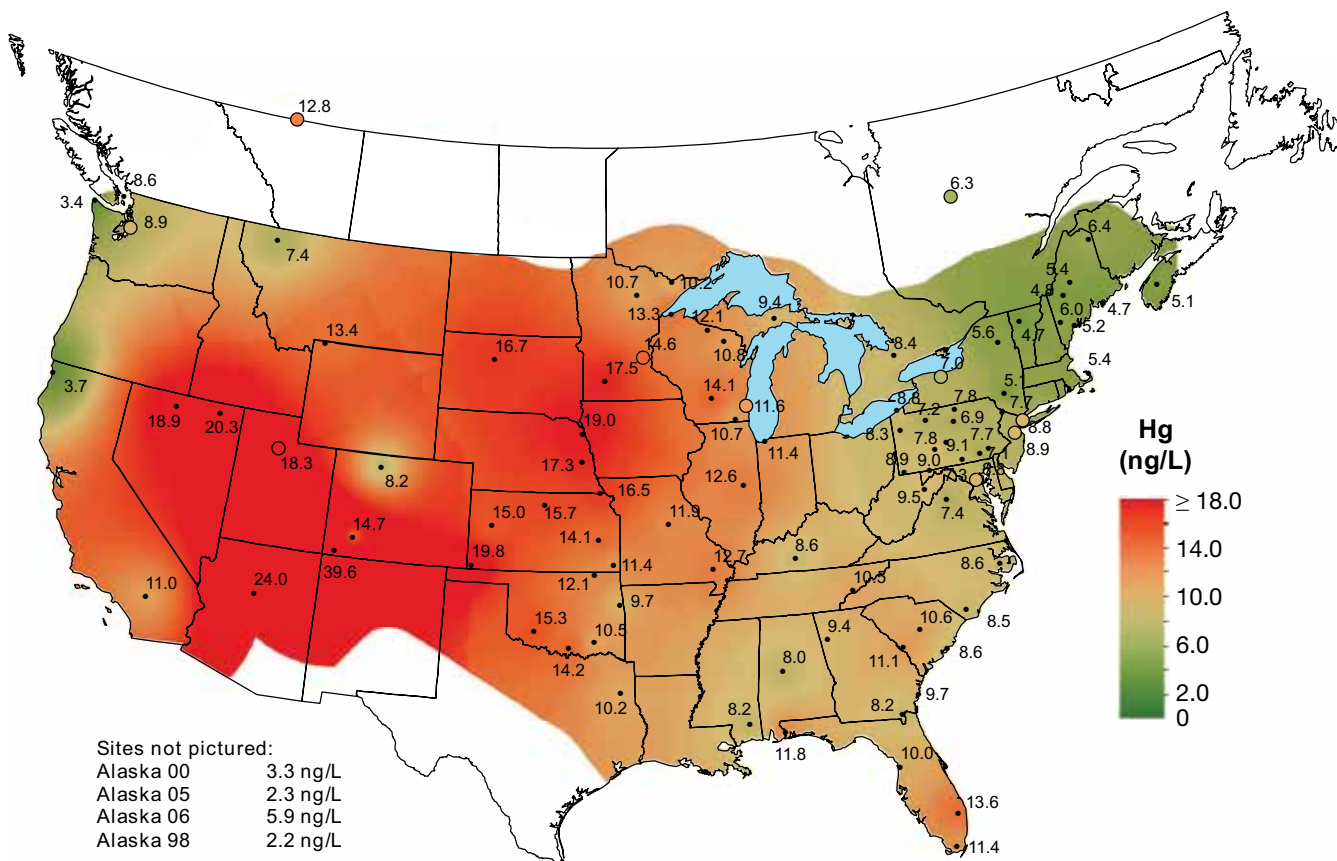
The MDN is the only network providing a long-term record for the concentration of mercury (Hg) in precipitation in North America. MDN sites follow standard procedures and use approved precipitation collectors and raingages. The automated collector is similar to the NTN collector, but it is modified to preserve mercury. Site operators collect samples either every Tuesday morning or daily within 24 hours of the start of precipitation. In 2012, the Devil's Lake site in south-central Wisconsin (WI131), the Underhill site in northern Vermont (VT99), the Yorkville site in northwestern Georgia (GA40), the Birmingham site in Alabama (AL19), and the Pensacola, Florida site (FL96) collected daily samples. Chemical analysis of the MDN samples is performed by the Mercury Analytical Laboratory (HAL) at Eurofins Frontier Global Sciences, Inc., Bothell, Washington.

All MDN samples are analyzed for total mercury concentration. In 2012, 16 MDN sites opted to measure methyl mercury concentrations. The HAL reviews field and laboratory data for accuracy and completeness, and identifies samples that were mishandled, compromised by equipment failure, or grossly contaminated. Data are made available on the NADP website (<http://nadp.isws.illinois.edu/mdn>).



MDN Maps

The maps on page 23 show spatial variability in the precipitation-weighted mean concentration and wet deposition of total mercury. Only sites meeting NADP completeness criteria are included. In 2012, 98 of 112 active sites met these criteria.



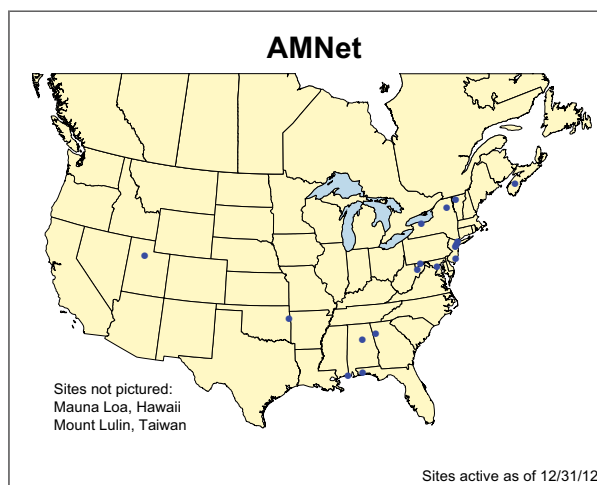
Total mercury concentration (top) and wet deposition (bottom), 2012.

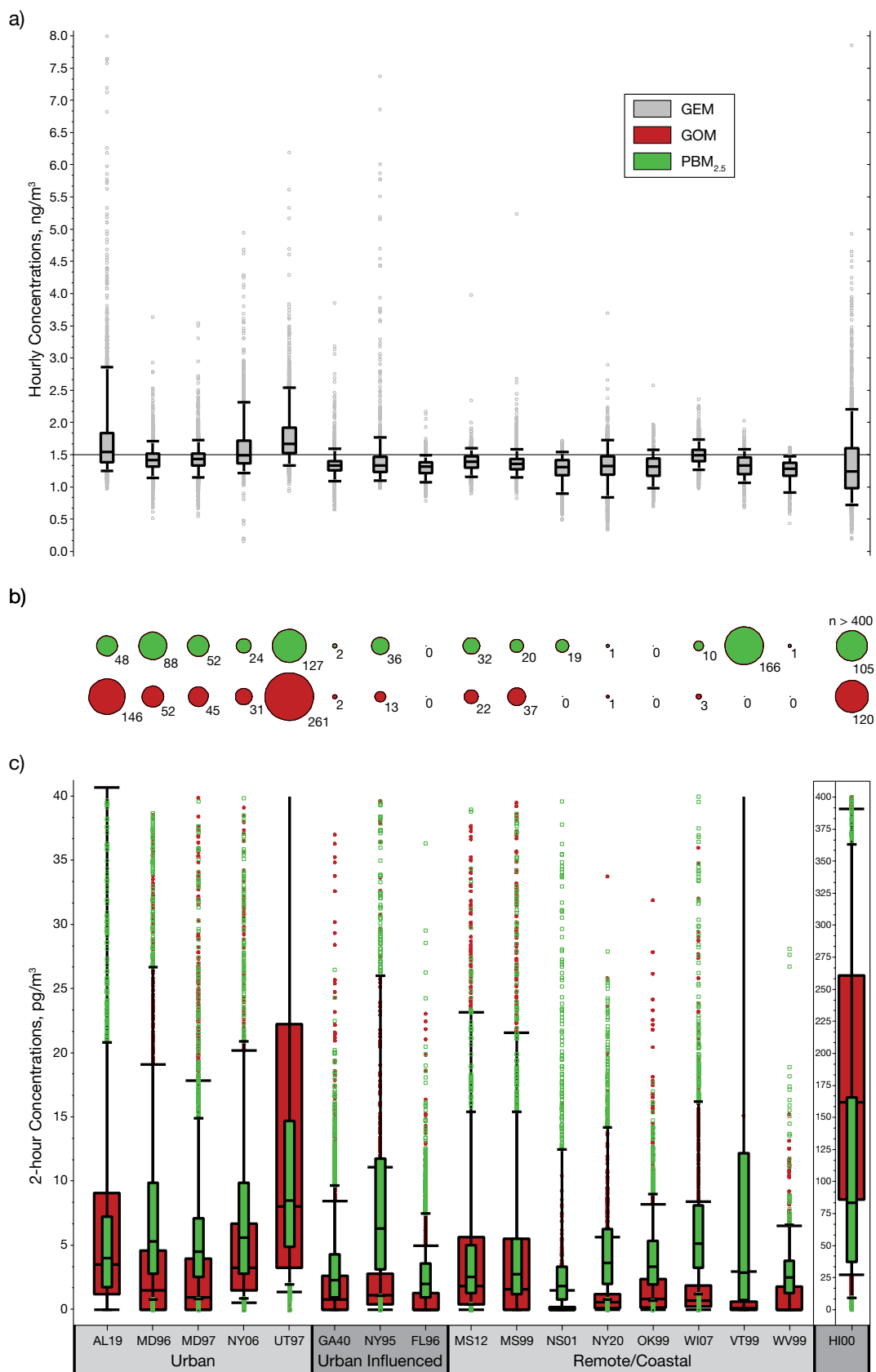
Atmospheric Mercury Network (AMNet)

AMNet sites measure atmospheric mercury fractions that contribute to mercury deposition. Sites measure concentrations of atmospheric mercury species (gaseous oxidized, particulate-bound, and elemental) using automated, continuous measuring systems. Measurements are made using standardized methods, and are quality assured.

AMNet measurements are made continuously (five-minute and two-hour averages). Data are qualified and averaged to one-hour (gaseous elemental mercury, GEM) and two-hour values (gaseous oxidized mercury, GOM, and particulate bound mercury, $\text{PBM}_{2.5}$). AMNet data are available on the NADP website at <http://nadp.isws.illinois.edu/amn/>.

The figures on page 25 show the distribution of atmospheric mercury concentrations for each site in 2012. Figure a shows the distribution of GEM in nanograms per cubic meter (ng/m^3). Figure b shows the distribution of two-hourly atmospheric concentrations of GOM, and $\text{PBM}_{2.5}$ in picograms per cubic meter (pg/m^3). Included as part of figure b is the number of valid GOM and $\text{PBM}_{2.5}$ observations that exceed $40 \text{ pg}/\text{m}^3$ ($400 \text{ pg}/\text{m}^3$ for HI00), the upper limit shown with the box plots.





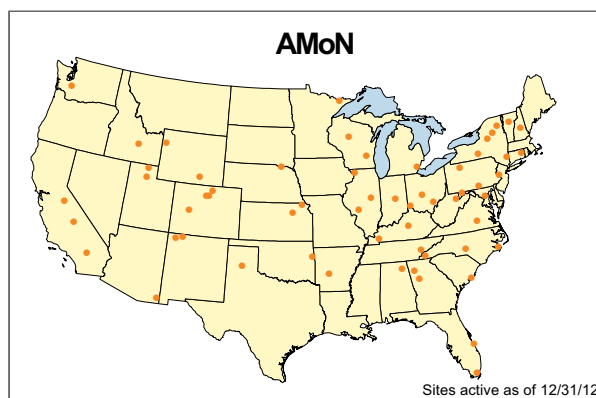
a) Hourly GEM concentrations in ng/m³ for each AMNet site and b) 2-hour GOM and PBM_{2.5} concentrations in pg/m³ for each AMNet site in 2012. The bubble chart indicates the number of valid observations for both GOM and PBM_{2.5} above 40 pg/m³ (400 pg/m³ for HI00), the upper limit shown with the box plots. Note the different scale for HI00 in figure b.

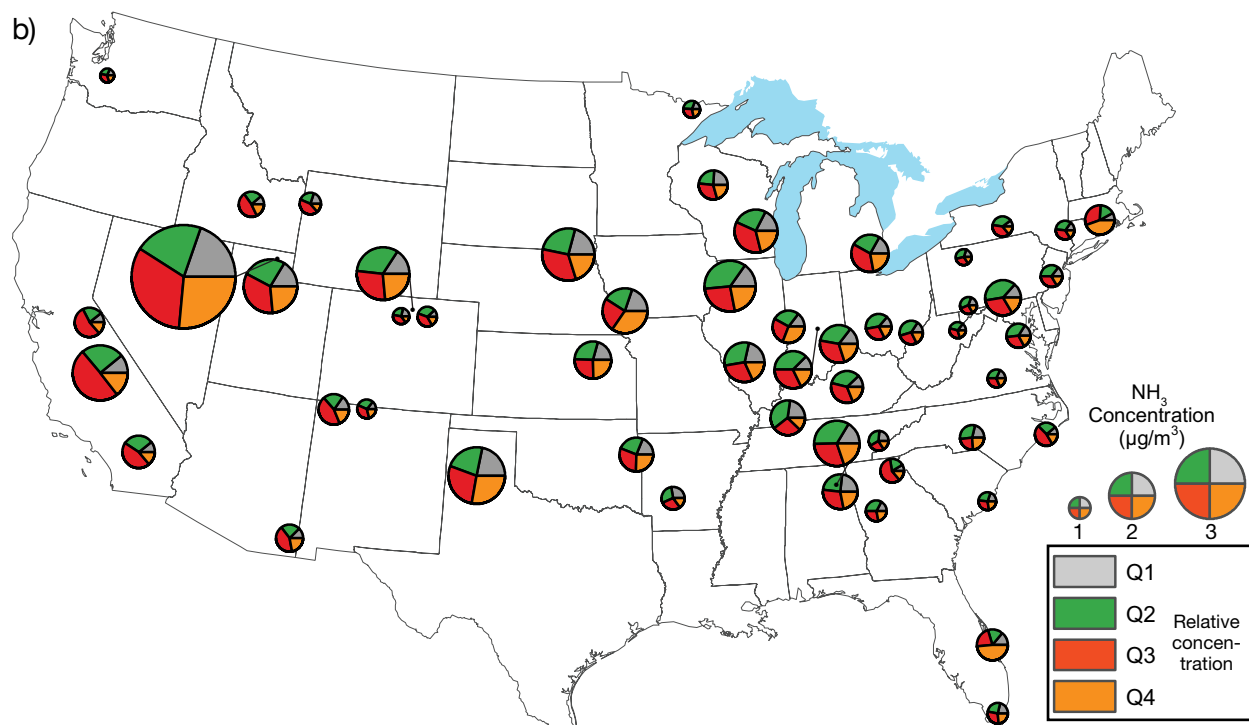
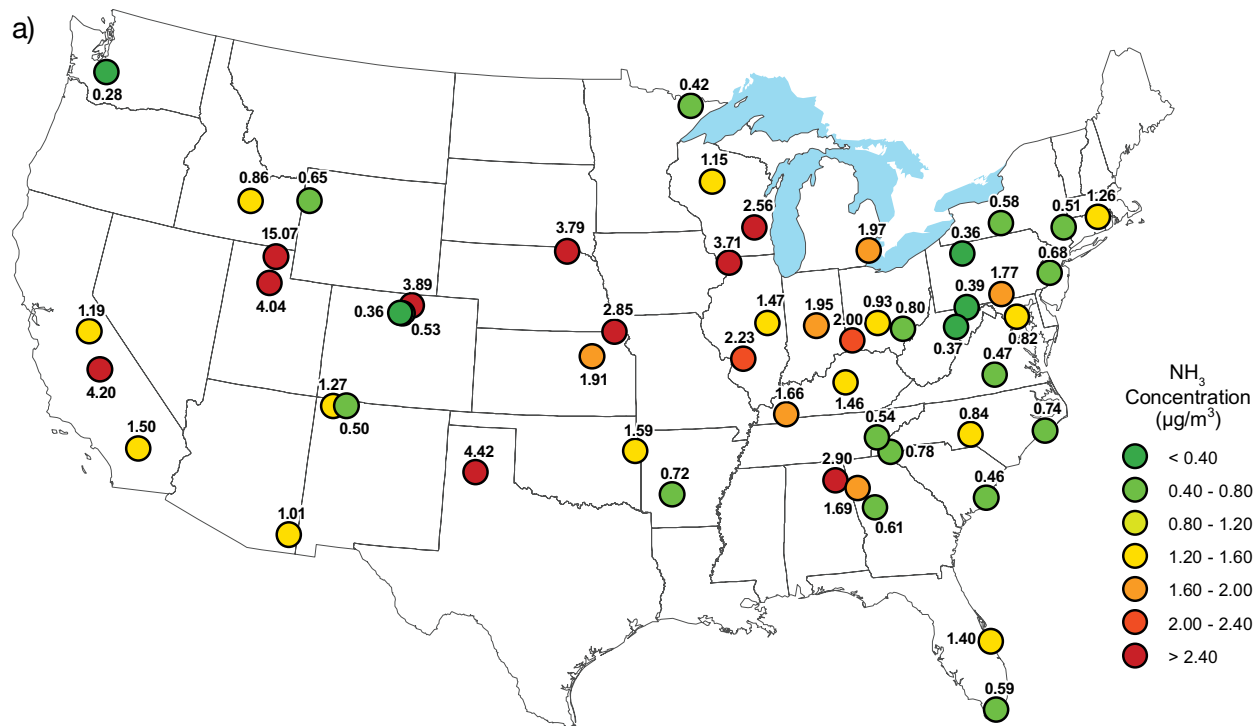
Ammonia Monitoring Network (AMoN)

The AMoN measures atmospheric concentrations of ammonia (NH_3) gas. The network uses passive diffusion-type samplers. This allows for cost-effective, straightforward, and simple measurements. Observations are made over a two-week period with some sites measuring in triplicate. This provides an integrated and quality-assured estimate of ammonia in the air. These data will be used to assess long-term NH_3 trends, provide necessary information for model development and verification, and assess changes in atmospheric chemistry.

At the end of 2012, there were 61 AMoN sites. Data are available on the NADP website at <http://nadp.isws.illinois.edu/amon/>.

The figures on page 27 show the distribution and seasonality of gaseous ammonia concentrations for each site meeting completeness criteria. In 2012, 53 of 61 active sites met these criteria. Circles in figure a represent annual average concentrations in micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) at each site. In figure b, the relative concentration for each site is shown for each calendar quarter. The size of the wedge is the relative percentage for the quarter. The size of the pie chart is proportional to the annual average for the site.





a) Average 2012 ammonia concentrations as measured by AMoN (in $\mu\text{g}/\text{m}^3$), and b) quarterly relative percentage (Q1 = January, February, March, etc.) for each AMoN site. Size of the symbol is relative to the annual concentration.



National Atmospheric Deposition Program

The NADP is the National Research Support Project-3: A Long-Term Monitoring Program in Support of Research on the Effects of Atmospheric Chemical Deposition. More than 250 sponsors support the NADP, including private companies and other non-governmental organizations, universities, local and state government agencies, State Agricultural Experiment Stations, national laboratories, Native American organizations, Canadian government agencies, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, the Tennessee Valley Authority, the U.S. Geological Survey, the National Park Service, the U.S. Fish & Wildlife Service, the Bureau of Land Management, the U.S. Department of Agriculture - Forest Service, and the U.S. Department of Agriculture - National Institute of Food and Agriculture, under agreement no. 2012-39138-20273. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the sponsors or the University of Illinois.

Champaign, IL: September 2013
ISWS Miscellaneous Publication 201 and NADP Data Report 2013-01
Editor: Lisa Sheppard; Layout: Sara N. Olson



<http://nadp.isws.illinois.edu>

All NADP data and information, including color contour maps in this publication, are available from the NADP website: <http://nadp.isws.illinois.edu>. Alternatively, contact: NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820, Tel: (217) 333-7871, Fax: (217) 333-0249, E-mail: nadp@isws.illinois.edu.

The NADP Program Office is located at the Illinois State Water Survey, a division of the Prairie Research Institute at the University of Illinois at Urbana-Champaign.